International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD)
ISSN (P): 2249-6866; ISSN (E): 2249-7978
Vol. 9, Issue 3, Jun 2019, 1-8

THE EFFECTS OF PARTIAL INTERACTION DEGREE ON REINFORCED CONCRETE ARCH BEHAVIOR

WALEED A. WARYOSH [1] & ENG. SHAIMA SABRI ALI[2]

[1]*Assistant Professor, Civil Engineering Department, Al-Mustansiriayah University, Baghdad, Iraq*

[2]*Ph. D Student, Civil Engineering Department, Al-Mustansiriayah University, Baghdad, Iraq*

ABSTRACT

The arch usually subject to multiple load relay on the position of arch such as dead, live and others which will produce stresses in the arch rib that are generally small compared with the axial compressive stress. The benefits of arch that works primarily in compression, and carries compressive loads, not tensile loads and the arch sustain loads better than straight beam. In present work four types of reinforced concrete arches and fifth arch without reinforced are tested under static loading at the center of the top face of the arches. The arches are different in spacing of stirrups for the T – section reinforced concrete arches. The tests results showed that the casted concrete in different stirrups has effects on the strength capacity of the concrete arches by increase the compressive strength of arches even when casted as full interaction reduced the deflections.

***KEYWORDS:** Reinforced Concrete Arches, Compressive Strength, Stirrups Full & Partial Interaction*

Received: Feb 16, 2018**; Accepted:** Mar 06, 2019**; Published:** Apr 09, 2019**; Paper Id.:** IJCSEIERDJUN20191

Original Article

INTRODUCTION

An arch is defined as a curved structural member spanning an opening and serving as a support for the loads above the opening [1]. In 1994, Jasim [2], present a method of analysis based on the linear elastic theory, which enabled the construction of design charts for estimating the mid-span deflection of simply supported composite beams with partial interaction. The study also presented a method of analysis to determine the influence of partial shear connection on free vibration of simply supported composite beams. In 2004, Oehlers and Park [3] studied the shear connectors in composite beams with longitudinally cracked slabs. A method of determining the dowel strength of shear connectors in longitudinally cracked concrete slabs with transverse reinforcement was derived. The method depends on the strength of the shear connector in longitudinally untracked slabs, as used in most design techniques, and on the stiffness of the transverse reinforcement. In 2004, Radić et al. [4], reviewed many constructional methods that adapted to constructed reinforced concrete arch bridges. The evaluated methods of constructions indicated that the development of free cantilever construction techniques for large and long concrete arch bridges was greatly improved through the construction of some bridges. In 2007, Quiroz [5], investigation focuses on the evaluation of full and partial shear connection in composite beams using the commercial finite element (FE) software ANSYS. In 2008, Cadoni et al. [6], studied the highway reinforced concrete arch subjected to high dynamic loading tested in situ. The test results were used as input data in the model that simulated the prototype bridge by finite elements analysis to check out the existing performance of bridge. In 2010, Heidarpour [7], presents a somewhat generic model for the nonlinear elastic behavior of composite arches subjected to sustained loading at elevated temperatures. The effect of partial interaction between the steel and

concrete components in the tangential direction, as well as the variation of internal axial compressive forces along the member, is taken into account. In 2012, Caglayan et al. [8], assessment arch concrete bridge under the effects of static and dynamic loadings by finite elements analysis. In 2014, Yang and Shieht 9, solved many structural problems included arch by taking into account the nonlinearity geometry behavior of the selected structural elements. In 2015, Khan et al. [10], extended the direct displacement–based design method that spliced for buildings and bridges to arch design, The analysis results showed that the suggested approach is capable to design the cases that take it into account because of gave closed results as compared with other approached.

In present work, the parameters that taking into accounts are the spacing of stirrups, the amounts of stirrups and the composite action. The effects of partial interaction degree on reinforced concrete arch behavior as experimental tests are examined.

An Experimental Program

The experimental program consisted of material mechanical properties, support and loading conditions and test methodology

Mechanical Properties of Materials

The average of three specimens are adopted at (28) days at the time of tested specimens as cubes, cylinders and prisms. The cement type is Ordinary Portland cement that mixed with the fine and coarse aggregate in which the maximum size of (4.75mm) and (10 mm) respectively.

Three specimens for each diameter of bars that adopt to reinforce all the structural arch specimens are tested. Tensile test of steel reinforcement is carried out on diameter (12 mm) and (10 mm), by taking specimen length (500 mm), the tests results list in Table 1

Table 1: Properties of Steel Reinforcement

Nominal Diameter(mm)	Yield Tensile Strength f_y (MPa)	Ultimate Tensile Strength f_u (MPa)	E_s (GPa)
12	410	610	200
10	405	596	200

Test Program

A total of five reinforced concrete arches specimens were tested. The arches specimens profile, configuration and details presented in Figure 1

Table 2: Specimens Details

Specimen Mark	Specimen Description	Compressive Strength fc' (MPa)	Stirrups Spacing (mm)
Arch 1(AR1)	reference	25	150
Arch 2(AR5)	Interaction effect	25	250
Arch 3(AR6)	Interaction effect	25	200
Arch 4(AR7)	Interaction effect	25	100
Arch 5(AR8)	Without reinforcement	25	------

The specimens are classified into five specimens relay on the spaces of strips. The height of arches for all the

specimens is (500 mm) at the bottom face of the arch, the length of arches (2100 mm), as shown in figure (1). The first specimen AR1 as reference arch to compare with other specimens and it reinforced with (10 mm) diameter of stirrups at (150 mm) center to center. Other specimens (AR5, AR6, AR7) with the same main reinforcement but different spacing stirrups (250, 200, 100) respectively except (AR8) without reinforcement.

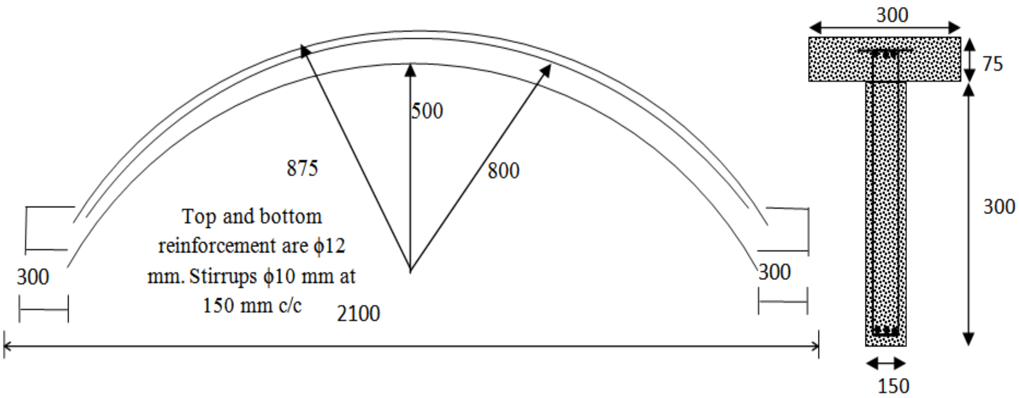

Figure 1: Arch Configuration and Geometry, all Dimensions in Mm

Support and Loading Conditions

The test arches are fixed over a span of (2100 mm) that represent the total arch span and loaded with one point load applied at the top face center of the arch span and distributed across the entire width of the arches by a solid rod up to failure as load control, as shown in figure 2

Figure 2: Applied Loading Setup

TEST PROCEDURE

The applied loadings for all specimens are gradually in small increments up to failure load to examine the full behavior. Deflections concrete are recorded for each load step. When the specimen reach advanced stages of loading (appearance of first crack), smaller increments of load are recorded up to (90%) from the ultimate loading then continued until failure of the specimen. The sides of each arch specimen are painted white to expose the formation of cracks during tests. The tests are carried out by using a universal testing machine brand as (8551 M. F. L. system) with capacity of

(3000 kN), as shown in Figure 2 Soft wooden boards are placed between the steel tubes and the base of the test frame to eliminate undesirable bearing stress concentrations and the effect of friction during test. In placing the specimens in the testing machine, care is taken to ensure concentric loading at the center of top face and prevent develop any torsion during test.

TEST RESULTS

Four differences reinforced concrete arches that mentioned in Table 2 that subjected to static load up to failure. Figures 3 to 7 shows the specimens before and after the test. The mode of failure is flexural for specimens. Figures 8 to 9 represents the full behavior of the load-deflections at arch center and at quarter of the arches span respectively. The behavior of all specimens linear up to the first crack loadings and then the behavior become nonlinear so that the curve directed toward the horizontal axis because of the concrete become weak due to increase in applied loading up to failure. Table 3 lists the summary of the test results.

Figure 3: Specimen Arch 1 Before and after Test

Figure 4: Specimen Arch 5 before and after Test

Figure 5: Specimen Arch 6 before and after Test

Figure 6: Specimen Arch 7 before and after Test

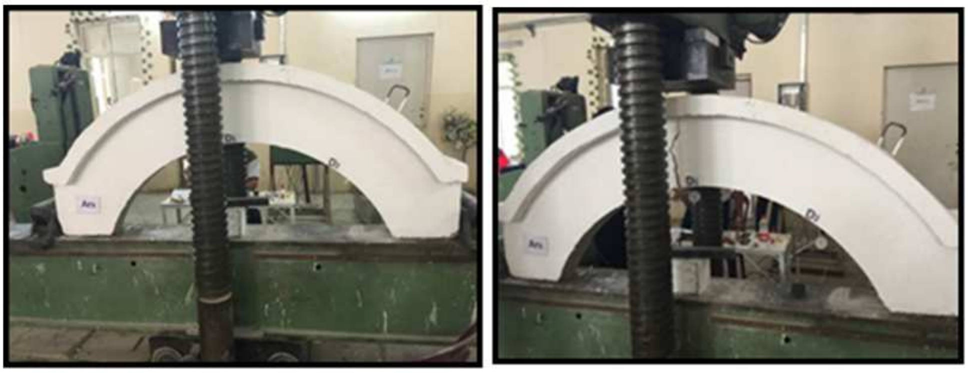

Figure 7: Specimen Arch 8 before and after test

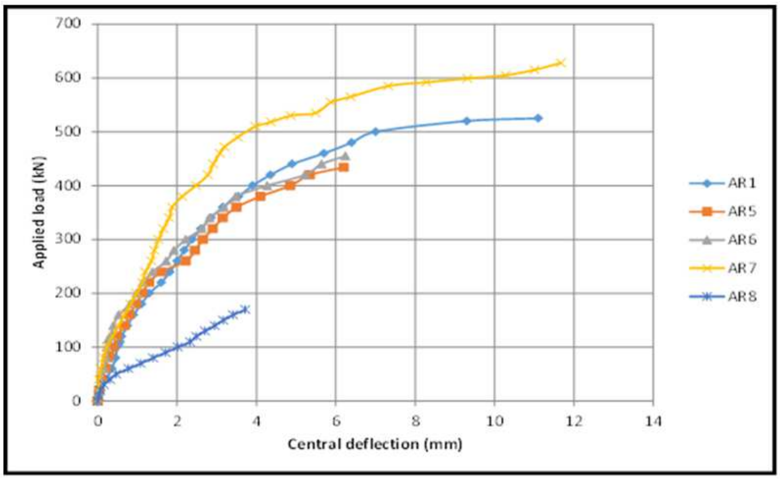

Figure 8: Load Deflections behaviors of all Specimens at Mid Span of the Arches

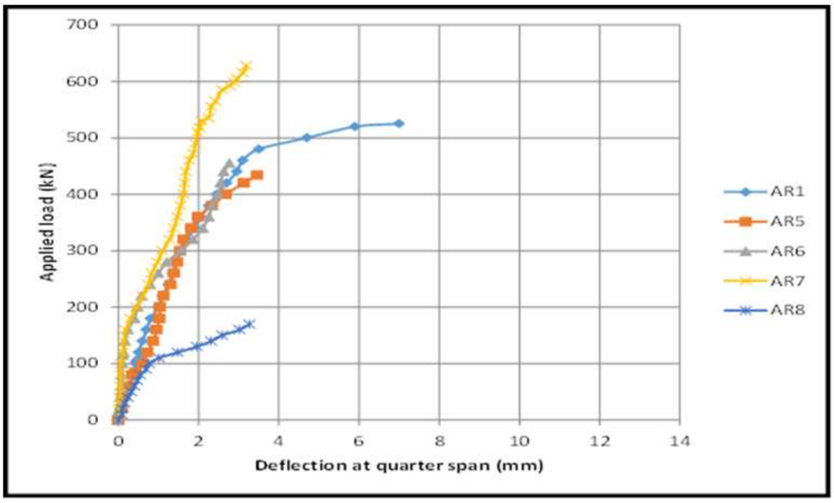

Figure 9: Load Deflections Behaviors of all Specimens at Quarter Span of the Arches

Table 3: Tests Results Summarized for all Specimens

Specimen Mark	First Cracking Load P_c (kN)	Deflection at First Cracks (mm)		Ultimate Load P_u (kN)	% of Change Related to Control Specimen	Deflection at Ultimate Load (mm)	
		Quarter Span	Central			Quarter Span	Central
AR1	105	0.45	0.53	525	0	7.00	11.10
AR5	85	0.25	0.30	434	-17.33	3.46	6.20
AR6	115	0.09	0.22	455	-13.33	3.77	6.26
AR7	180	0.20	0.55	628	19.62	3.19	11.67
AR8	50	0.17	0.55	170	-67.62	3.26	3.72

DISCUSSIONS

The specimen (AR5), the load capacity is (434 kN) compared with the control specimen (AR1) there was reduced in strength about (17.33%). The amounts of stirrups make the reinforced concrete arch work as partial between the flange surface bottom area and web so that shear stresses will developed at the interface. The maximum deflection at the center and quarter of the arch span is (6.20 and 3.46 mm) respectively. The deflection of (AR1) at the same ultimate load of (AR5) is (5.1 and 2.92 mm) as shown in figure (4.4) and (4.5).

The specimen (AR6), the load capacity is (455 kN) compared with the control specimen (AR1) there was reduced in strength about (13.33%). The amounts of stirrups are more than that of the specimen (AR5), center to center spacing is (200 mm) rather than (250 mm) for (AR5). The reinforced concrete arch work also as partial compared with (AR1). The maximum deflection at the center and quarter of the arch span is (6.12 and 3.77 mm) respectively. The deflection of (AR1) at the same ultimate load of (AR6) is (4.9 and 2.85 mm).

The specimen (AR7), the load capacity is (628 in) compared with the control specimen (AR1) there was an increase in strength about (19.62%). The amounts of stirrups are more than that of the specimen (AR1), center to center spacing is (100 mm) rather than (150 mm) for (AR1). The reinforced concrete arch work as full compared with (AR1) and other specimens has same mechanical properties and main reinforcement's configuration. The maximum deflection at the center and quarter of the arch span is (11.67 and 3.19 mm) respectively. The specimen (AR8), the load capacity is

(170 kN) compared with the control specimen (AR1) there was decrease in load capacity around (67.62%) because of no reinforcements embedded in section so that the arch specimen worked as plain concrete and resist only applied load only by compression resistance. The load capacity of the specimen Arch 7 gave large value than others specimens

CONCLUSIONS

Based on the tests results and the observations during tests that showed the spacing of stirrups for full and partial connection will effects on the behavior and strength of the reinforced concrete arches even when casted at different spaces. Specimen Arch 7 gave increased in strength capacity around (19.62%) as compared with the Arch 1. Deflections at quarter and mid span decreased with increased in compressive strength of concrete because of increased in modulus of elasticity of concrete. The loading required to appear the first crack increased as the compressive strength increased because of increased in internal capacity of the specimens. The cracks developed and appear from the mid span of the specimens and then propagated started from the bottom face of the specimens up to top face due to increase in applied loading up to failure. Partial or full interaction between flange and web relay on the amounts of stirrups, so that in case of less amounts of stirrups that developed slip and the capacity reduced. The reduced in capacity in specimen compare with control specimen is 17.33% and 13.33%. The cracks that developed due to applied loading distributed uniformly along the specimens that located at or near the mid-span. When the spacing of stirrups decreased and within limits, the shear strength capacity increased because of the shear reinforcements with the surrounding concrete work as full interaction.

REFERENCES

1. *Chung C. Fu and Shuqing Wang, "Computational analysis and design of bridge structures", CRC Press, First edition, 2015.*
2. *Jasim, N. A., "The Effect of Partial Interaction on Behavior of Composite Beams", Ph. D. Thesis, University of Basra, Iraq, 1994.*
3. *Oehlers, D. J., and Park, S. M., "Shear Connectors in Composite Beams with Longitudinally Cracked Slab" Journal of Structural Engineering, Vol.118, No 8, August 1992, p 2004.*
4. *Radić et al. "Construction Methods for Reinforced Concrete Arch Bridges," DAAAM Int. Sci. B., 2004.*
5. *Queiroz, F. D., Vellasco, P. C. G. S., & Nethercot, D. A. (2007). Finite element modelling of composite beams with full and partial shear connection. Journal of Constructional Steel Research, 63(4), 505-521.*
6. *Nagaral, M., Auradi, V., & Ravishankar, M. K. (2013). mechanical behaviour of aluminium 6061 alloy reinforced with al2o3 & graphite particulate hybrid metal matrix composites. International Journal of Research in Engineering & Technology (IJRET) Vol, 1, 193-198.*
7. *Cadoni et al.,"High strain-rate testing of concrete and steel for the assessment of theTenza Bridge under blast loading " , University of Applied Sciences of Southern Switzerland,2008.*
8. *Heidarpour, A., Pham, T. H., & Bradford, M. A. (2010). Nonlinear thermoelastic analysis of composite steel–concrete arches including partial interaction and elevated temperature loading. Engineering Structures, 32(10), 3248-3257.*
9. *Caglayan "Assessment of a concrete arch bridge using static and dynamic load tests," Struct. Eng. Mech., vol. 41, no. 1, pp. 83–94, 2012.*
10. *YANG and SHIEH, "Solution method for nonlinear problems with multiple critical points," AIAA J., vol. 28, no. 12, pp. 2110–2116, 2014.*

11. *AL-Shammari, M. A. A., & AL-Gaffar, S. A. Experimental and Theoretical Study in Rubber Reinforced with Carbon Fillers under Tension–Cyclic Load.*
12. *Khan et al., "Direct Displacement–Based Seismic Design of Reinforced Concrete Arch Bridges," J. Bridg. Eng., vol. 19, no. 1, pp. 44–58, 2015.*